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COLLEGE OF AGRICULTURE UNIVERSITY OF NEBRASKA
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 42

STEM RUST IN NEBRASKA

PART I. GENERAL SURVEY OF SOURCES

PART II. IDENTIFICATION OF THE PHYSIOLOGIC FORMS OF PUCCINIA GRAMINIS FROM VARIOUS SOURCES

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LINCOLN, NEBRASKA
July, 1927

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STEM RUST IN NEBRASKA

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PART I. GENERAL SURVEY OF SOURCES

INTRODUCTION

Since the inception of the barberry eradication campaign in 1918 in Nebraska, the question has continually been asked, "Will the eradication of the barberry in the state eliminate or materially reduce stem rust?" In order that an answer might be obtained, an investigation to determine the sources of primary infection of stem rust on cereals was inaugurated in the spring of 1921. Altho these studies have been carried on for 6 years, no definite statement regarding the relative importance of the primary sources and the amount of stem rust prevalent in the state from season to season originating from these sources can be made. However, a general idea of the rust situation which existed during these years in Nebraska can be deduced from the results herewith presented.

DISTRIBUTION AND IMPORTANCE OF SMALL GRAINS IN NEBRASKA

Winter and spring wheat, oats, barley, and rye constitute the important small grain crops grown in Nebraska. The average combined acreage of all these crops for 1921-25 was 6,395,580, which consisted of 3,162,547 acres of winter wheat, 234,172 acres of spring wheat, 2,520,993 acres of oats, 235,889 acres of barley, and 241,979 acres of rye.

The distribution of winter and spring wheat is shown comparatively by Figures 1 and 2. The winter wheat varieties most generally grown in Nebraska are of the Hard Red winter type, including Nebraska No. 60, Kanred, and Turkey. Marquis is one of the leading spring wheats grown. This is especially true in western Nebraska, where the bulk of the crop is raised. Oats are grown in all parts of the state, but most of the acreage is confined to the eastern half. The total acreage of barley is small in comparison with winter wheat and oats and is more or less scattered over the state, being somewhat more concentrated in the southwestern counties. Very little wheat, oats, and barley are raised in the sandhill region, which includes in part the north central counties.

Acknowledgment is made to Dr. H. B. Humphrey, Senior Pathologist, Office of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, for aid in the preparation of the manuscript.

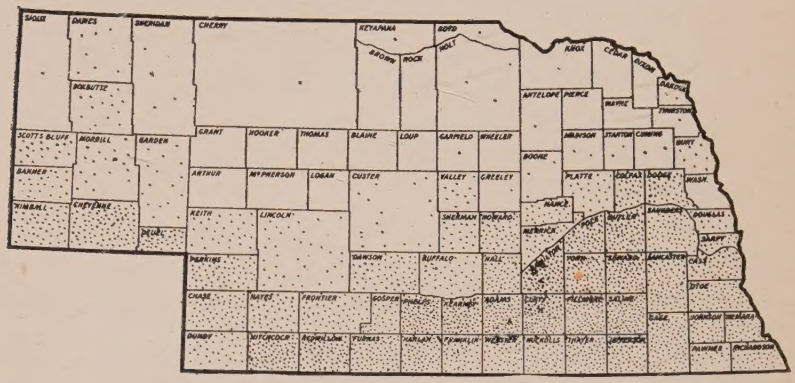

FIG. 1.— Distribution of winter wheat. Each dot represents 1,000 acres. Average for years 1921-1925. Data from Neb. Agr. Statistics, Neb. Dept. of Agr.

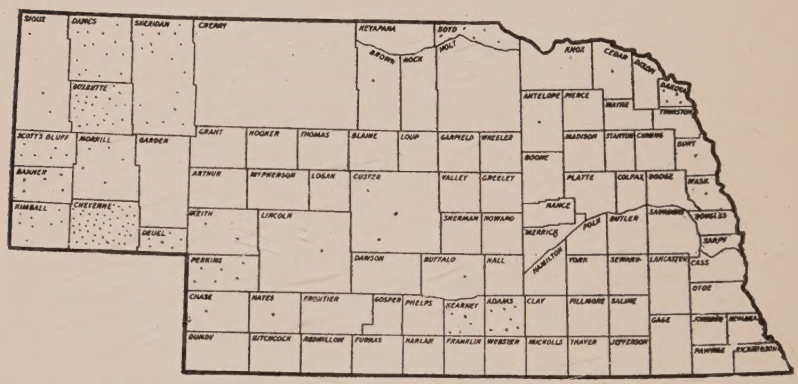

FIG. 2.— Distribution of spring wheat. Each dot represents 1,000 acres. Average for years 1921-1925. Data from Neb. Agr. Statistics, Neb. Dept. of Agr.

Rye is also scattered over the state in very small acreages, but most of it is grown in the sandhill region.

Besides the small grains mentioned above, a number of common wild grasses, which are also subject to stem rust, are widely scattered over the state. Some of these grasses, commonly observed to be rusted, may be listed in order of their prevalence and distribution over the state: *Hordeum jubatum, Agropyron smithii, Elymus canadensis, E. virginicus,* and *Hordeum pusillum.* These grasses are susceptible in varying degrees to both the *tritici* and *secalis* forms of *Puccinia graminis.* Only three grasses, *Koeleria cristata, Dactylis*

glomerata, and *Arrhenatherum elatius*, susceptible to the *P. graminis avenae* are found in Nebraska.

PRIMARY SOURCES OF RUST IN NEBRASKA

There are 3 possible primary sources of stem rust *(Puccinia graminis*, Pers.) of small grains in Nebraska:

(1) Overwintering urediniospores and mycelium.

(2) Aeciospores from the common barberry.

(3) From either one or both of these sources outside of Nebraska.

(1) OVERWINTERING OF UREDINIOSPORES AND MYCELIUM OF PUCCINIA GRAMINIS

Carleton (2) in 1897 found uredinia of *Puccinia graminis tritici* (Pers.) Erikss. and Henn. on wild barley *(Hordeum jubatum)* and of *P. graminis avenae* (Pers.) Erikss. and Henn. on tall oats grass *(Arrhenatherum elatius)* and orchard grass *(Dactylis glomerata)* as late as November 16, at Lincoln, Nebraska.

Peltier (8) has summarized five years' results from overwintering studies in Nebraska as follows: "After the month of January, no urediniospore germination was obtained from naturally infected wheat plants in the field, and no urediniospores developed on plants inoculated and incubated in the greenhouse, placed under various conditions in the field and subsequently brought back into the greenhouse. It is extremely doubtful whether overwintering of the urediniospores of stem rust can occur under field conditions by means of an extended period of incubation. Thus, it is safe to conclude from 5 years' results that the urediniospores of *Puccinia graminis tritici* do not overwinter under conditions that exist at Lincoln, Nebraska."

One of the writers (Thiel) independently conducted experiments on the overwintering of the urediniospores from different parts of the state, during the winters of 1921 to 1925. During the fall of each of these years, extensive observations were made for uredinial material in the winter-wheat fields and on the susceptible grass hosts. In no instance was more than a trace found on winter wheat in the fall. In many fields it could be found only on volunteer winter wheat. *Hordeum jubatum* and *Agropyron smithii* were the two grass hosts usually infected with the wheat and rye forms of rust and *Dactylis glomerata* with the oat form. If it was possible to find these grass hosts in a green condition, uredinial material was present. In cases of heavy infection, an abundance of urediniospores could always be found between the leaf sheath and stem. Germination tests were made once a month during

the winter with the wheat form of rust. Table 1 shows the percentage of spore germination obtained in distilled water during the winter months of 1923-24. The results were typical of those obtained during the other 4 years. Laboratory tests showed that the percentage of viable urediniospores remained relatively high during October and November. In December the viability decreased frequently to 40 per cent, during January to 5 per cent, and by the last of February only a trace of germinating spores could be found. During March a trace of viable spores was sometimes present, but in April no germination was obtained. Many of the urediniospores probably perish early in the winter on account of the sudden changes of temperature. Those which survive germinate before the environmental conditions are favorable for infection on grains or grasses.

Stakman (13) has found that the urediniospores of stem rust overwinter in the region south of San Antonio, Texas, and that they do not survive the winters north of Dallas, Texas.

Baringer (1), in Ohio, states that, "The writer has been unable to discover stem rust on growing wheat during the autumn in which it was sown. For these reasons it is believed that there is a decided scarcity or perhaps a complete absence of viable urediniospores of *P. graminis* on either volunteer or fall-sown grain during the winter."

Walker and Thompson (15), in Wisconsin, conclude that, "Practically all red spores perish early in the winter. The remainder are killed by the freezing and thawing weather thruout the later winter and early spring."

Durrell and Lungren (3), working in Colorado, summarize their results as follows: "Studies on the overwintering of stem rust urediniospores have been conducted in Colorado during five years. These red rust spores on wild barley have been found to germinate until late spring, but no natural infection or spread has ever been found which was traceable to this source."

The results of the investigations of these workers substantiate the findings of the writers, and it may be concluded that the urediniospores of stem rust do not overwinter in the northern states including Nebraska.

(2) THE COMMON BARBERRY IN NEBRASKA AS A SOURCE OF STEM RUST

The barberry eradication campaign in Nebraska began April 1, 1918. Since that time, every city, town, village, and farm of the state has been surveyed for the common barberry. A second survey also has been made in 22 of the eastern counties. The distribution and approximate location of the properties having barberries in each county is shown in Figure 3. During the 9 years, from 1918 to 1926, inclusive,

TABLE 1.—*The percentage of viable urediniospores of Puccinia graminis tritici collected from winter wheat during the different months of the winter 1923-24 in Nebraska.*

Location	Time of germination tests	Percentage of germination for each month	Average percentage of germination of all stations for each month
Lincoln	December 15	40	46.4
North Platte	December 15	48	
Scottsbluff	December 15	50	
Beatrice	December 15	43	
Fremont	December 15	51	
Lincoln	January 15	5	4.8
North Platte	January 15	4	
Scottsbluff	January 15	2	
Beatrice	January 15	6	
Fremont	January 15	7	
Lincoln	February 15	1	1.6
North Platte	February 15	2	
Scottsbluff	February 15	1	
Beatrice	February 15	2	
Fremont	February 15	2	
Lincoln	March 15	0	0
North Platte	March 15	0	
Scottsbluff	March 15	0	
Beatrice	March 15	0	
Fremont	March 15	0	

97,711 common barberry bushes and 13,306 seedlings were found and destroyed on 4,045 properties. In the reinspection of properties, 16,587 sprouting bushes were found and destroyed.

In the 22 counties in which a second survey has been completed, common barberries were found on an average of 15 properties for each county. On this basis it is reasonable to expect that bushes still exist on approximately 600 properties in the 40 counties remaining to be surveyed. These counties are located in the eastern half of the state, where the barberries have been found to be most numerous in the past (fig. 3).

Numerous observations were made each spring for rust infected barberries and they have been found thruout the state. The map (fig. 4) shows the counties and the years in which aecia of *Puccinia graminis* have been observed on the common barberry from 1918 to 1926.[1] It will be noted that barberries have been found rusted practically over the entire state. In fact aecia on barberries have been found one or

[1] The data on barberry infections from 1918 to 1920 were obtained under the direction of Dr. E. Mead Wilcox.

more times during the 9 years in 70 of the 84 counties in which barberries were found. By referring to the map in Figure 4, it will be observed that no barberries were found in some of the counties. This accounts for the absence of data in the remaining 9 counties. The presence of data from a county does not indicate that all barberries observed were rusted; neither does their absence mean that the conditions were unfavorable for barberry infections. It was not possible to make observations for barberry infections in every county each year. Likewise, the number of barberries and sprouts remaining from year to year have gradually decreased. Consequently, in those counties where there were few barberries originally, or where their complete eradication was successful in one year, only a few observations were possible. The general infection of barberries during the 9 years shows clearly that they were a potential source of stem-rust inoculum in every part of the state.

As a rule, the rust infections on barberries were heaviest in the counties bordering the Platte River. Pound (10) in 1889 made observations on rust infections on barberries in Lancaster County and stated as follows:

"Rather common. Often distorts the leaves to such an extent as to seriously injure the bushes."

The degree of infection on barberries varies from year to year, according to the weather conditions of the previous summer, fall, and spring. Stakman et al (12) have reported that barberries do not rust in the south, because practically no teliospores are viable in the spring. The teliospores are developed normally but lose their viability during the hot, dry summer and fall. This same condition exists in certain localities during certain years in Nebraska.

Melander and Craigie (4) in their extensive studies show that leaves of the common barberry 10 days or more old are fairly resistant to *Puccinia graminis*. Dry weather during April will delay the germination of those teliospores which have retained their viability, and when moisture conditions do become favorable many of the barberry leaves may be too old for the successful penetration by the germ tubes of the sporidia.

The wheat form, *Puccinia graminis tritici*, and the rye form, *P. graminis secalis*, were the only physiologic forms observed spreading from barberries. No clear, convincing case of the oat form, *P. graminis avenae*, has been observed spreading from barberries in this state. Some of the grass hosts which are susceptible to the oat form of rust are not common in Nebraska. The oat form has been observed on orchard grass *(Dactylis glomerata)*, but not on tall oat grass

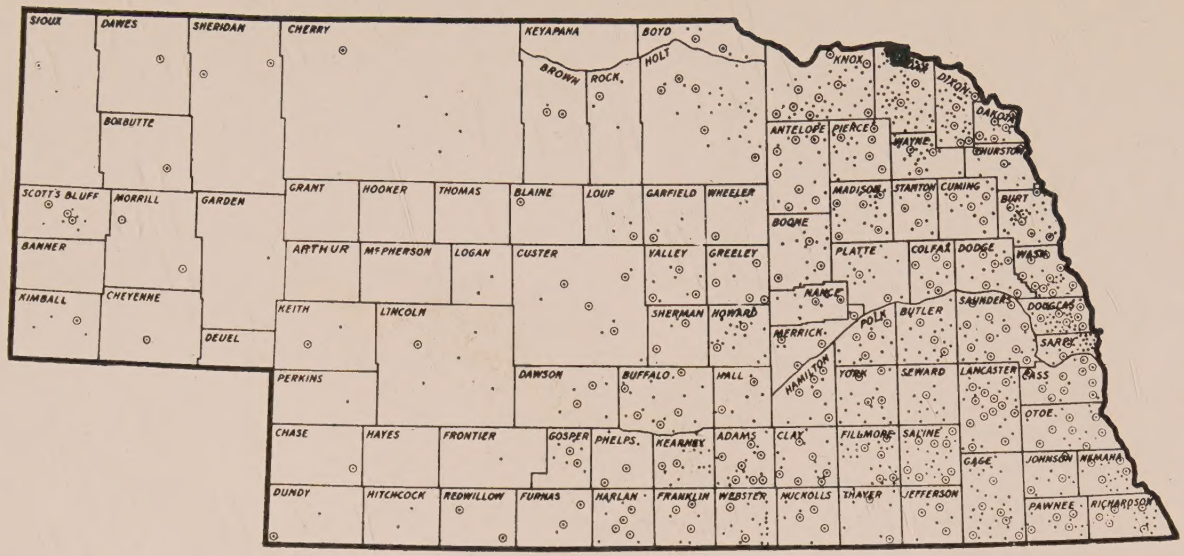

FIG. 3.— Approximate location of 4,045 properties on which 97,711 barberry bushes were found and destroyed. 1918-26. Each dot represents one farm, while the dot and circle represents towns where barberry bushes have been located.

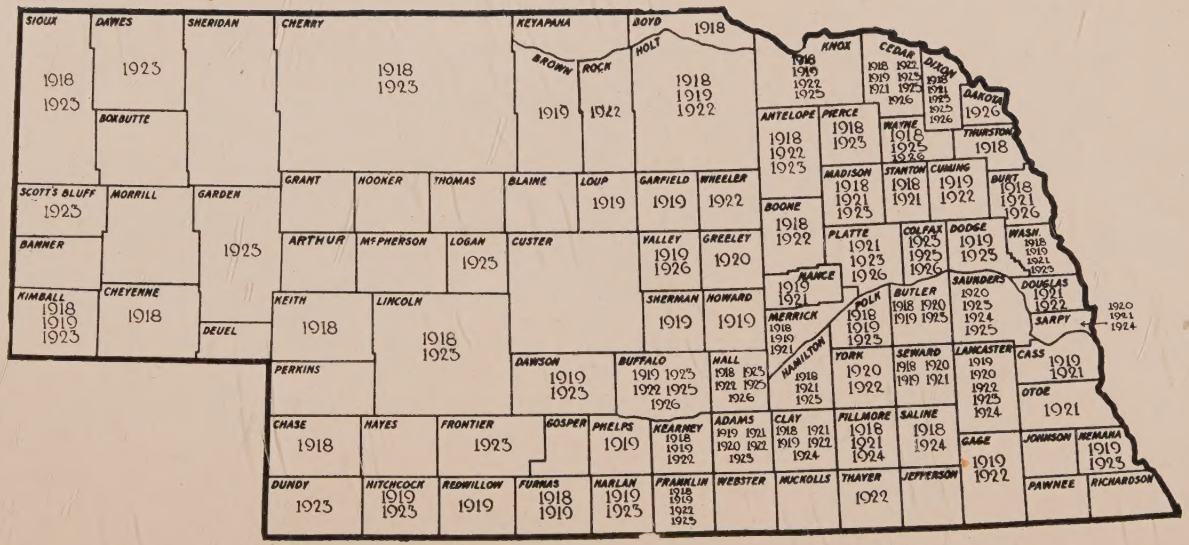

FIG. 4.— Counties in which aecia of *Puccinia graminis* have been found on the common barberry with the respective year the observation was made. 1918-26.

(Arrhenatherum elatius) and prairie June-grass *(Koeleria cristata)*. The latter 2 grasses usually occur in the native prairie and are not found around the homesteads. Consequently, if the oat form of rust does occur on these grasses they are not near enough to barberry bushes to infect them. Orchard grass is not very common in this state. Consequently, it is not very important as a host for this rust. The oat straw is usually fed to stock, and the oat stubble is plowed under in the fall. Hence the scarcity of teliospore material of the oat form of stem rust to infect the barberry in the spring.

The date of the earliest appearance of stem-rust infections on barberries and grasses or grains is shown in Table 2. In every instance, the observations for the appearance of pycnia, aecia, and uredinia were made at the same location for a given year. The pycnia normally made their appearance from April 20 to 26, aecia from May 6 to 10, and uredinia from May 20 to May 25. In 1924, the season was later than normal and the pycnia, aecia, and uredinia did not appear until May 14, May 28, and June 9, respectively, while in 1926, the driest spring in 40 years was responsible for delayed infection of the barberry.

In 1909, Wilcox and Stone (17) stated in their report that barberries were rusted in some localities early in the spring and that wheat was always much more severely rusted in the vicinity of a barberry hedge.

The writers have studied the spread of rust from barberries each year from 1921 to 1926. Figure 5 shows the counties in which these studies have been made and also the dates of the observations. Susceptible grasses were usually found near barberries. Consequently, in most instances, the first uredinia were on grasses which were immediately under or near the barberry bushes (Table 3).

Typical cases of spread of stem rust from barberries in Nebraska have been shown by Wilcox (16) in 1919, and by Thiel (14) in 1925. The diagram in Figure 6 shows a typical case of spread of stem rust from barberries to winter wheat in Hamilton County, June 24, 1925. The first few uredinia were found on *Hordeum jubatum* near the two infected bushes on May 21. By May 25 a few uredinia were found on winter wheat, a hundred feet north of the bushes. By June 24 the rust had spread over the entire forty-acre wheat field. The barley in the adjoining oat field also was rusted. The prevailing wind from May 20 to June 10 was from the south. This accounts for the heavier rust infection in the field toward the north. The manner in which barberries are responsible for local centers of stem-rust distribution therefore should be clear.

(3) THE FIRST APPEARANCE OF STEM RUST NOT DIRECTLY TRACEABLE TO BARBERRIES

During the last 2 weeks of May or the first week of June, careful observations [1] were made to find the first uredinia appearing on grains not directly traceable to barberries in the different parts of Nebraska. Observations extending over a period of 6 seasons show that some of this scattering of stem rust over the state comes from areas outside of Nebraska. The first uredinia not directly traceable to barberries always were found in the southern counties before they were observed elsewhere in the state (figs. 7 and 8). The primary infections usually consisted of a single uredinium. Occasionally a group of uredinia were found on the leaf and stem (pl. 1). These first uredinia were so rare that it was often necessary to search several hours before finding one.

The data obtained in the general survey for the first appearance of stem rust not directly traceable to local barberries for each of the 6 years are briefly outlined as follows:

TABLE 2.—*Earliest date of the appearance of pycnia, aecia, and uredinia of Puccinia graminis in eastern Nebraska 1921-26.*

Year	County	Pycnia	Aecia	Uredinia
1921	Adams	April 20	May 8	May 20
1922	Adams	April 21	May 6	May 22
1923	Colfax	April 25	May 10	May 25
1924	Lancaster	May 14	May 28	June 9
1925	Hamilton	April 26	May 9	May 21
1926	Colfax	May 3	May 18	May 25

1921. Stem rust was general on winter wheat in very small amounts thruout the northeastern tier of counties in Kansas during the last week in May. A few uredinia were found in the counties of southeastern Nebraska by June 6 (fig. 7). By June 21 rust was found in the northern counties and as far north as Salem, South Dakota. There was a general but light infection of stem rust thruout Nebraska. The severity of infection on the plants was less than 5 per

[1] Thanks are due Mr. B. F. Dittus and Mr. P. W. Rohrbaugh, Federal Agents in Barberry Eradication, for efficient help in making these observations.

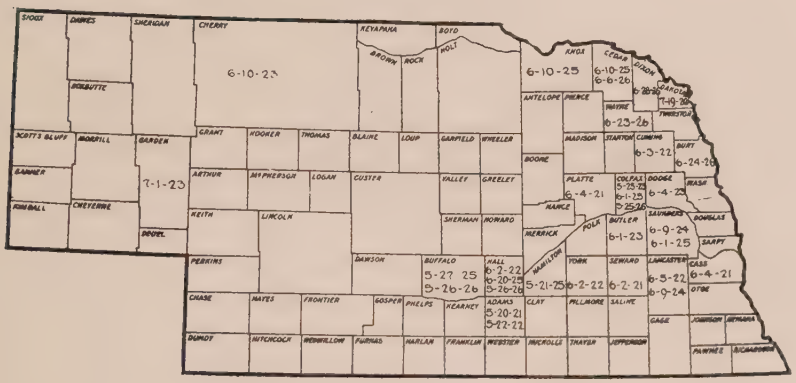

FIG. 5.— Counties in which stem rust on grains and grasses was traceable to barberries and the dates when the observations were made. 1921-26.

cent. There was no apparent damage to any of the small grains.

1922. Stem rust was found a few days earlier than in the previous season. By May 20 rust made its appearance at Salina, Kansas. On June 2 a trace was found on winter wheat in Gage County, Nebraska, and by June 12 rust was observed in the northern counties of Nebraska and at Yankton, South Dakota (fig. 7). There was a slight, scattered infection of stem rust; much less than in 1921. Owing to unfavorable weather conditions the winter wheat matured early, and the harvest was the earliest on record.

1923. During the last week of May, the first uredinia of stem rust were found on winter wheat in Kansas near Augusta, Minneapolis, Clay Center, and Salina. On June 6 it was first observed at Hebron, Nebraska. One week later rust was found in the central counties, and by June 20 it appeared in the northern and western counties of Nebraska (fig. 7). There was much damage to both spring and winter wheat in the western part of the state. The grain matured later than normally, and the weather conditions were most favorable for rust development. Many fields of wheat remained unharvested because of severe damage by rust, and much of the wheat which was threshed was very poor in quality.

1924. Daily observations were made during the first 2 weeks of June and no stem rust was found until June 17. This was 2 weeks later than the previous year. On this day it was found on winter wheat at Concordia and Belleville in Kansas, and in Jefferson, Thayer, and Fillmore Counties in Nebraska. On the following day uredinia were collected

TABLE 3.—*Counties in which the spread of stem rust from barberries was studied, the dates when the observations were made, and hosts infected, 1921-26.*

County	Date of observations	Hosts infected with the uredinial stage
Adams	5/20/21	*Agropyron smithii* and winter wheat
Seward	6/ 2/21	Winter wheat
Cass	6/ 4/21	*Agropyron smithii* and *Hordeum jubatum*
Platte	6/ 4/21	*Hordeum jubatum* and winter wheat
Adams	5/22/22	*Agropyron smithii* and winter wheat
Hall	6/ 2/22	*Hordeum jubatum* and winter rye
York	6/ 2/22	*Hordeum jubatum*
Cuming	6/ 3/22	*Hordeum jubatum*
Lancaster	6/ 5/22	*Agropyron smithii* and winter wheat
Colfax	5/25/23	*Agropyron smithii*
Butler	6/ 1/23	*Hordeum jubatum*
Dodge	6/ 4/23	*Hordeum jubatum*
Cherry	6/10/23	Winter rye
Garden	7/ 1/23	Winter wheat
Lancaster	6/ 9/24	*Agropyron smithii*
Saunders	6/ 9/24	*Agropyron smithii* and winter wheat
Hamilton	5/21/25	*Hordeum jubatum* and winter wheat
Buffalo	5/27/25	*Agropyron smithii*
Colfax	6/ 1/25	*Agropyron smithii* and winter wheat
Saunders	6/ 1/25	*Hordeum jubatum*
Cedar	6/10/25	*Hordeum jubatum* and barley
Knox	6/10/25	*Hordeum jubatum*
Hall	6/20/25	*Hordeum jubatum* and winter wheat
Colfax	5/25/26	*Agropyron smithii* and winter wheat
Buffalo	5/26/26	*Agropyron smithii*
Hall	5/26/26	*Agropyron smithii*
Cedar	6/ 6/26	*Hordeum jubatum*
Wayne	6/23/26	*Hordeum jubatum* and barley
Burt	6/24/26	*Hordeum jubatum*
Dixon	6/28/26	*Hordeum jubatum*
Dakota	7/19/26	*Hordeum jubatum* and barley

northward as far as Platte County. Observations were made in several fields in each county and only a few uredinia were found in each field. Observations also were made on June 18 in Madison and Pierce Counties, and on June 19 in Butler, in northern Seward, and northern Lancaster Counties and no stem rust was found. It was impossible to find stem rust north of Platte County until a week later. At that time, on June 24 and 25, it was observed beyond the northern border of Nebraska and one uredinium was found on winter wheat between Sioux City, Iowa, and Yankton, South Dakota. It also appeared in the western counties at this time (fig. 8). There was no appreciable loss to small grains due to stem rust, altho environmental conditions were most favorable for stem rust infection and development.

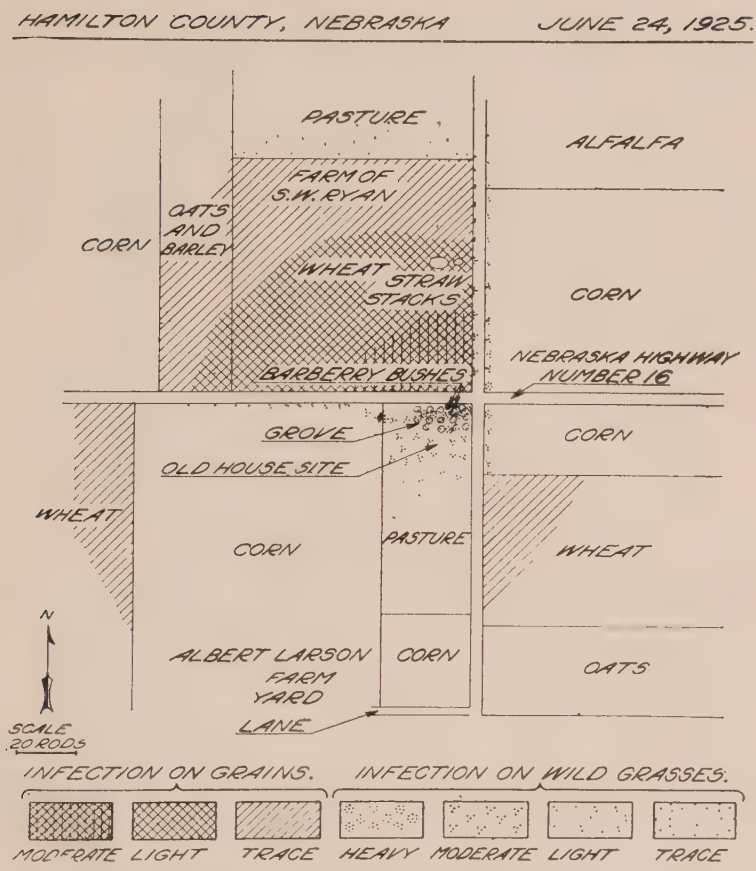

FIG. 6.— Diagram showing the spread of stem rust of wheat from barberries to grains and grasses, June 24, 1925, Hamilton County, Nebraska.

1925. The first uredinia not directly traceable to local barberries were found on winter wheat in Jefferson County on June 8 (fig. 8). The same observer collected uredinia northward during the next 4 days across the entire state. A second observer stationed in the northern counties found the first uredinia on June 10. This was the first time in 5 years that stem rust not directly traceable to local barberries was found in the northern counties almost as soon as in the southern counties. The continuous southern winds during the last week in May and the first week in June of this year may have been responsible for a wider distribution of the infection material.

There was no damage due to stem rust on any of the early maturing cereal crops. There was less stem rust on winter wheat than occurred during the previous 4 years. There was a moderate infection of stem rust on late spring wheat and late oats. On spring wheat the average severity was 20 per cent, and prevalence 90 per cent. On late oats the average severity was 30 per cent, and prevalence 90 per cent. Only a trace of stem rust was found on winter rye.

1926. Observations for stem rust began May 27. Three observers made daily observations in Jefferson, Thayer, Nuckolls, Butler, Colfax, Cedar, and Pierce Counties. No uredinia were found until June 4, when a few pustules were found on winter wheat in Nuckolls, Thayer, and Jefferson Counties. On June 8, a few uredinia were found in Lancaster and Pierce Counties. From June 12 to 17, stem rust was found in the central and western counties of the state (fig. 8). There was a general distribution of stem rust of wheat over the entire state by the third week in June. The environmental conditions which prevailed during June were not favorable for further rust development, and consequently there was very little rust in winter wheat at harvest time. There was no loss due to stem rust in wheat, barley, and rye. There was a slight loss in late oats.

DISCUSSION

Summing up the data obtained from the general survey of the primary sources of stem rust in Nebraska we may conclude that the urediniospores of stem rust do not overwinter in the state.

Barberries have been found rusted at one time or another thruout the state. The degree of infection has naturally varied from year to year and from locality to locality, depending on the weather conditions of the previous summer, fall, and spring, influencing the oversummering and subsequent germination of the teliospores and the age of barberry leaves at the time sporidia are mature.

During 4 years, pycnia were first observed on barberry between April 20 and 26, aecia with mature spores between May 6 and May 10, while uredinia on grasses and grains near infected barberries were first noted May 20 to May 25. Thus, under normal spring conditions in Nebraska, the time interval between the appearance of pycnia and mature aecia is approximately 15 days, and from mature aecia to uredinia on grasses and grains about the same interval.

As a rule barberries may be found producing aecia up to about the middle of June. New aecia frequently appear on the new tender leaves after a period of moist weather conditions.

PLATE 1.— A typical group of primary uredinia of stem rust of wheat.

The first uredinia near rusted barberries have been found primarily on the grasses *Hordeum jubatum* and *Agropyron smithii,* as well as on wheat, rye, and barley. No early uredinia have ever been observed on oats adjacent to rusted barberries anywhere in the state, which leads one to surmise that the *avenae* form on barberries is not prevalent in Nebraska.

The first uredinia on grains not directly traceable to local barberries have usually been found in northern Kansas the last 10 days in May, while they have appeared in the southeastern tier of counties in Nebraska some time during the first week in June.

The initial appearance of rust in western Nebraska is appreciably later than in the eastern part. The seasonal development of cereal crops is one to three weeks later. Precipitation, relative humidity, and temperatures are much lower. Morning dews are not as numerous and the number of days having conditions favorable for infection would be much less. The later development of rust in this western section is probably due to the above factors, particularly moisture, in combination with the amount of inoculum present.

No uredinia not directly traceable to local barberries have ever been found in northern Nebraska prior to their appearance in the southern section of the state, from which one might conclude that there is a general movement of rust into Nebraska either directly or as successive rust generations.

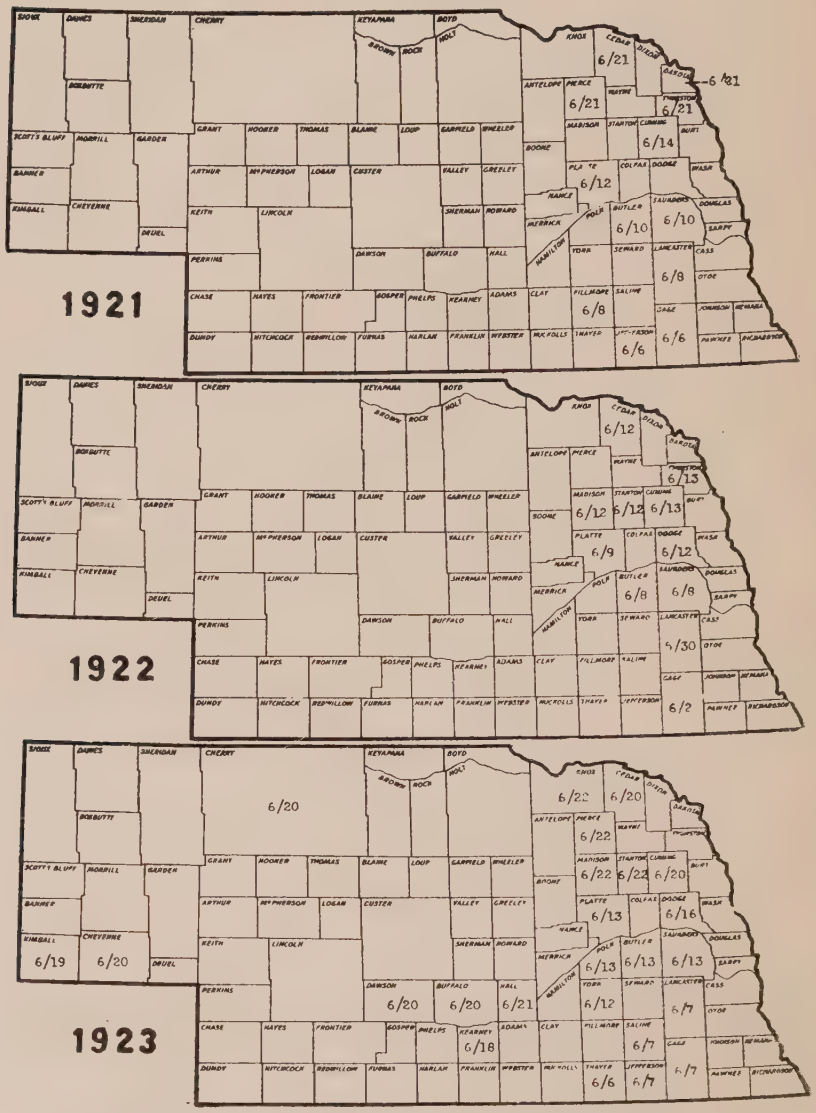

FIG. 7.— Dates of the first appearance, in certain counties of uredinia of stem rust on winter wheat not directly traceable to infected barberries. (1921-1922-1923.)

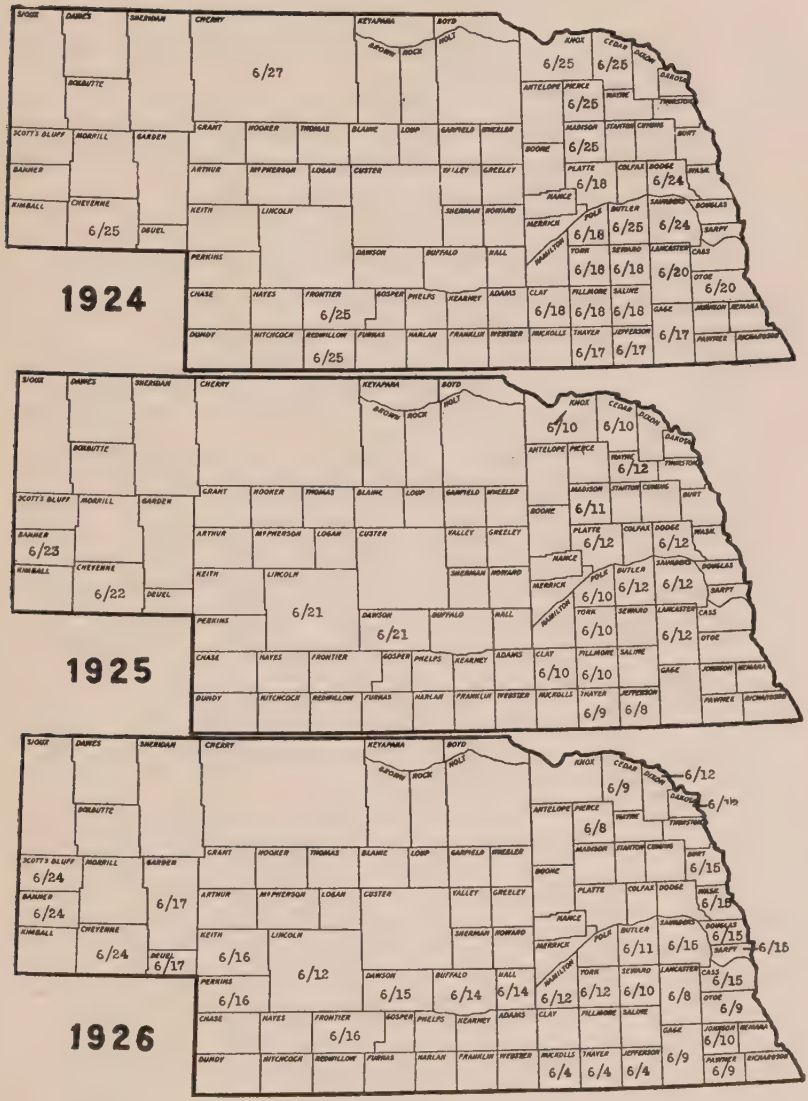

FIG. 8.— Dates of the first appearance, in certain counties, of uredinia of stem rust on winter wheat not directly traceable to infected barberries. (1924-1925-1926.)

It is interesting to note that the time interval between the appearance of uredinia in southern and northern Nebraska varies from year to year. From 1921 to 1924, when these studies were made by one observer, the interval was 15, 10, 13, and 8 days, respectively, while in 1925 and 1926, when three men made simultaneous observations at different places in the state from south to north, only 2 and 4 days' interval, respectively, were found. During normal years we can expect to find uredinia in the western end of the state about 12 to 15 days later than in the southeastern section.

Judging from these results we can conclude that during normal years the first uredinia are produced near rusted barberries about May 20 to 25, while the first uredinia not directly traceable to local barberries are normally found in southeastern Nebraska the first week in June. Within a week they are found in northern Nebraska and in western Nebraska in about 2 weeks. It is also true that this early infection of rust is found scattered in very small amounts over a wide territory, as compared to the heavier infection of rust near the barberry.

Thus, while we may at times have an earlier primary source of rust directly from the barberry than from the rust which appears later from undetermined sources, the former is centered locally around the barberry, while the latter is more scattered and widespread. The eradication of the barberry will eliminate this local infection.

There has been a gradual reduction in stem-rust losses during the last 6 years. During this time there has been a gradual decrease in the number of remaining barberries. The decreased number of barberries from year to year has likewise decreased the amount of infectious material. On the other hand, lack of sufficient moisture, during the last 3 years, was unfavorable for the development of stem rust localized around the remaining infected barberries and that originating from sources outside of Nebraska. The gradual decrease in the amount of stem rust can be attributed in part to both factors.

PART II. IDENTIFICATION OF THE PHYSIOLOGIC FORMS OF PUCCINIA GRAMINIS FROM VARIOUS SOURCES IN NEBRASKA

INTRODUCTION

While such a survey as the foregoing gives a general idea of the primary sources of stem rust in Nebraska, it does not indicate how much rust originates from barberries or from other sources. Furthermore, the physiologic forms of *Puccinia graminis* spreading from barberries cannot be identified in the field except in a few instances when certain nearby

grains or grasses are attacked. As rye is a minor crop in this state, and as no clear case of the oat form of rust has been observed spreading from barberries to oats, we were especially interested in the spread of the physiologic forms of wheat rust from the above mentioned sources.

In an effort to ascertain more completely the primary sources of stem rust, the identification of the physiologic forms of *Puccinia graminis* and the physiologic forms of *P. graminis tritici* from numerous collections of rust material from near barberries, and thruout the state was begun in 1924 and carried on for three seasons.

METHODS

The majority of the rust collections were made by one of the writers and his assistants. Each collection was placed in a paraffin envelope with notes and forwarded to Lincoln. Immediately on arrival, the collections were assigned accession numbers and placed in humidity chambers held at about 50 per cent relative humidity. These chambers were stored in a cold storage room held at 5° C. Here the material was kept until conditions in the greenhouse were favorable for infection, when it was withdrawn as desired and built up on stock plants. This method of storing rust collections thru the summer proved to be very advantageous in many respects (7).

The methods of inoculating and culturing the rusts were similar to those already described by one of the writers (6). Seed of the differential hosts sufficient for several years' needs was obtained thru the courtesy of Mr. J. Allen Clark, Office of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, in the fall of 1924.

All rust cultures were maintained in a greenhouse at 25° C. in individual compartments built of cheesecloth (pl. 2). These compartments served to break the air currents, thus avoiding any contamination of the cultures. A special watering device was also employed, so that no water ever reached the leaves of the plants. This device was fitted with a long glass tube which was disinfected each time that the plants in a compartment were watered.

The greenhouse was fumigated each week as a precaution against insects. All pots were placed in a copper sulfate solution and scrubbed when discarded. In the 6 years that rust cultures have been carried along in the greenhouse, no mixtures or contaminations of any rust cultures have occurred.

The inoculated plants were placed in incubation chambers maintained at about 23° C. In order that a regular schedule

could be carried out thruout the winter, a series of 1,000-watt Mazda C lights, with deep bowl reflectors, were suspended about 3 feet over the compartments and benches where stock plants were grown. These lights were used solely to supplement sunlight during cloudy days.

Seven-day-old plants were used thruout the investigations. All rust collections were built up and maintained on Little Club wheat, rye or barley. For identifying the physiologic forms of the rust collections, 30 plants of each differential host were inoculated. After 48 hours' incubation, they were placed in the compartments. Two weeks after inoculation all readings were made by one of the writers and checked by the other. The readings and subsequent identifications were based on the work of Stakman and Levine (13). If mixtures of forms occurred, they were again cultured from single pustules, built up, and reidentified. Two and occasionally three forms would sometimes be isolated from one collection. Every effort was made to grow the plants and cultures of rust under as uniformly optimum conditions thru the season as was possible with the control equipment available (9), so that in the results herewith reported the element of fluctuating variations might be reduced to a minimum.

RESULTS OF IDENTIFICATION OF PHYSIOLOGIC FORMS IN 1924

A total of 130 collections were made during the summer of 1924 in the 93 counties of the state (fig. 9). Fourteen of these collections represented primary pustules, collected June 17 to June 25; 100 were collected in July, and 16 were obtained in October on fall-sown or volunteer wheat. From the host standpoint, 89 collections were on winter wheat, 14 on spring wheat, 19 on *Hordeum jubatum*, 7 on barley, and 1 on wild rye.

Two collections were made on wild grasses directly under infected barberries during the month of July. When transferred to Little Club wheat in the fall, in the greenhouse, no subsequent infection resulted. Either the urediniospores were not viable or they did not represent the *tritici* form of *Puccinia graminis*.

Three physiologic forms were identified from the collections of primary pustules not directly traceable to local barberries, the dates of which are shown in Figure 8. Form 11 was identified from material gathered on winter wheat in Thayer County and on *Hordeum jubatum* from Madison and Knox Counties; Form 12 on *Hordeum jubatum* from Knox County; and Form 18 on winter wheat in Platte County. Form 11, as shown in Figure 8, was identified from primary pustules not directly traceable to barberries, collected within

a few days' interval, in 3 counties south and north in the state.

As the majority of the rust collections (100) were made in July and include secondary and succeeding generations of uredinia, they will be discussed under two headings. The physiologic forms which were found only occasionally and were limited in distribution are as follows:

Uncommon physiologic forms:

Form 6, Howard County
Form 12, Boyd County
Form 17, Chase and Hitchcock Counties
Form 24, Sherman and Thayer Counties
Form 25, Gosper County
Form 29, Cass and Sherman Counties

All but one of the physiologic forms were identified from rust collected on winter wheat and were found in different localities of the state (fig. 10). Since the summer of 1924, a number of barberry bushes have been found in the general locality where Form 6 was collected and it is barely possible that it originated from barberry.

As can be seen from Figure 10, Form 12 was found as a primary infection on *Hordeum jubatum* in Knox County on June 25. Barberries have been destroyed on 20 properties in this general region since 1924. This form was picked up in Boyd County on spring wheat two weeks later. It can be assumed that this infection probably originated from the earlier infection reported in June, as this form was not found anywhere else in the state.

Two collections of Form 17 were made on the same day in the southwestern section of the state in 2 counties. In the fall it was again found in eastern Nebraska, so that it was probably more prevalent than the data show.

Forms 24 and 29 were identified from the same collection in Sherman County. Both of these forms were found in other localities, one in Thayer County, the other in Cass County in eastern Nebraska. Barberries have since been found within a mile or two of the location where the material was collected in Sherman County.

The one collection from Gosper County was identified as Form 25. Here again barberries have been destroyed in the same general neighborhood since that time.

It is significant to note that barberries have been eradicated from the localities where these uncommon forms were collected and none of them has again been identified from rust material collected in Nebraska.

The physiologic forms which were frequently found and had a wide distribution are as follows:

Prevalent physiologic forms:

Form 3. Burt, Clay, Deuel, Dixon, Douglas, Knox, Merrick, Nance, Otoe, and Wheeler Counties.
Form 10. Arthur, Gage, McPherson, and Madison Counties.
Form 11. Box Butte, Buffalo, Cherry, Colfax, Cuming, Fillmore, Furnas, Garfield, Hall, Hamilton, Hayes, Keith, Keyapaha, Knox, Logan, Loup, Nance, Nemaha, Pawnee, Perkins, Polk (2), Richardson, Rock, Seward, Sheridan, and Sioux Counties.
Form 18. Cedar, Gage, Harlan, Jefferson, Kearney, Kimball, and York Counties.
Form 21. Red Willow, Saline, Saunders, and Stanton Counties.
Form 32. Custer, Dodge, and Scotts Bluff Counties.
Form 34. Adams, Banner, Butler, Dundy, Frontier, Johnson, Knox, Seward, and Stanton Counties.
Form 36. Boone, Dakota, Franklin, Hall, Nuckolls, Phelps, Thurston, and Webster Counties.

With the exception of the collection made in Deuel County, Form 3 was confined to the eastern half of the state. It was collected 10 times in as many counties. Likewise, Form 18 appeared with one exception to be scattered over the same region. While collected 7 times in as many counties, it was fairly widespread. Form 36, likewise, seems to have been found only in eastern Nebraska and particularly the southern half of the state, a total of 8 collections in as many counties were obtained. While limited in the number of times (4) identified, Forms 10 and 21 had fairly wide distribution. Form 32 was identified from collections made in the extreme western, eastern, and almost the exact center of the state. While it has a state-wide distribution, it was not abundant judging from the number of collections made. The distribution of Form 34 also was state-wide, 9 collections from as many counties being identified. The dominant and prevailing physiologic form thru Nebraska in the summer of 1924 was Form 11. During July it was collected 27 times from 26 counties and in distribution was state-wide.

During the month of October, 16 collections were made on volunteer or fall-sown wheat, in 12 counties south of the Platte River, to determine whether the physiologic forms prevalent in the late fall were the same as those obtained from the primary pustules in June and from the material collected in July. It is interesting to note that all the physiologic forms found in the fall were picked up during the summer in this region in almost the same relative proportion. A total of 6 physiologic forms were identified from the fall collections, as follows:

PLATE 2.— General view of the rust greenhouse, showing the inoculation bench in the background, the side bench with stock plants, the rust compartments, and the arrangement of the lighting system used to supplement sunlight on cloudy days.

Form 3. Johnson and Hall Counties.
Form 11. Butler (2), Lancaster, and Seward Counties.
Form 17. Butler County.
Form 18. Cass, Fillmore, Hamilton, and Saunders (2) Counties; also from Fairview, Kansas.
Form 21. Clay County.
Form 36. Otoe, Seward, and York Counties.

The Forms 3, 11, 18, and 36, most prevalent in this particular region during the summer, were those most commonly found in the fall. Forms 10 and 32 found in other sections of the state were not found, while Form 17, present only in western Nebraska, occurred once. Form 34 was not identified from any collection made in the fall.

To summarize: 14 physiologic forms of *Puccinia graminis tritici* were found in Nebraska during the summer of 1924. Of these, 6 were found only occasionally and were more or less scattered over the state, while 8 had a rather wide distribution. Form 11 was by far the most prevalent and dominant form, being found early as primary infection during the summer in all parts of the state, and again in the fall on volunteer and fall-sown wheat.

RESULTS OF IDENTIFICATION OF PHYSIOLOGIC FORMS IN 1925

During the season of 1925, a total of 100 rust collections were made of which 88 were obtained in 41 counties (fig. 9) in Nebraska. During the month of May, 8 collections were made in Hall, Hamilton, and Dawson Counties — 5 of aecia on barberry, and 3 of uredinia on wild grasses near barberries. An attempt was made to run this material to wheat, oats, and rye immediately after collecting, but owing to unfavorable conditions in the greenhouse no infections were obtained. In the fore part of June, 3 collections of aecia, uredinia on barley, and *Hordeum jubatum* near the infected bushes, made in Knox County, failed to develop on wheat or rye in the greenhouse in the fall, after storage thru the summer. Likewise, a rust collection made on *Agropyron smithii* found under infected barberries in Colfax County failed to develop infection in the greenhouse on wheat or rye. In Knox County, where a survey for the common barberry was in progress during June, a light infection of rust was observed on *Hordeum jubatum* near rusted barberries in the vicinity of Bloomfield, while considerable rust was found on timothy. No infection was obtained on wheat, oats, and rye from the collection made on *H. jubatum* in the vicinity nor from 3 other localities in this county near rusted barberries. The rust from timothy was placed on wheat, oats, and rye, but only a weak infection was obtained on rye.

On June 12, aecia from barberry and uredinia on *Hordeum jubatum* and *Elymus* sp. growing directly under the bushes near Belleville, Kansas, were collected. The *secalis* form of *Puccinia graminis* was obtained from both grasses.

It is hard to interpret our unsuccessful attempt to infect wheat, oats, and rye in the greenhouse, with rust material on the wild grasses collected under or near infected barberries. It can be stated here, however, that during the 1925 season our infection experiments in the greenhouse with the rust material collected were not as successful as those of the preceding summer. Environmental conditions prevailing during the early summer may be partly responsible for the lack of viability of the spores.

Four physiologic forms were identified from the collections of primary pustules, the dates of which are shown in Figure 8. Form 18 was identified from material collected on winter wheat in Knox County about one mile from barberry; Form 21 on winter wheat in Lancaster and Lincoln Counties; Form 31 on winter wheat in Fillmore and Lincoln Counties; and Form 36 on winter wheat in Thayer, Fillmore, and Lancaster (2) Counties.

Collections sent on June 6 from Norman, Oklahoma, and June 8 from Salina, Kansas, on winter wheat, were identified as Form 36. Unfortunately, a number of primary infections not directly traceable to barberries, made during the early part of June from south to north in Nebraska, were lost when an attempt was made to transfer this material in the greenhouse in the fall, so that only a part of the history of the rust situation was obtained. The fact that Form 36 was obtained in Oklahoma and Kansas and first appeared in the southern part of Nebraska, then north in Fillmore and Lancaster Counties, leads one to assume that Form 36 entered Nebraska from the south.

Beginning about June 17, secondary infections began appearing in eastern Nebraska, while they did not develop in western Nebraska until about July 1. During the latter part of June and the month of July, the majority of the rust collections were rather poor, in that telia were beginning to form, which accounts for the high mortality when this material was transferred to seedling wheat in the greenhouse. Forty-six collections, 28 on winter wheat, 9 on spring wheat, 7 on barley, and 2 on *Hordeum jubatum,* were made during the summer.

The following physiologic forms were identified from this material:

Form 18. Box Butte (2), Hayes, and Sheridan Counties.
Form 21. Nuckolls County.

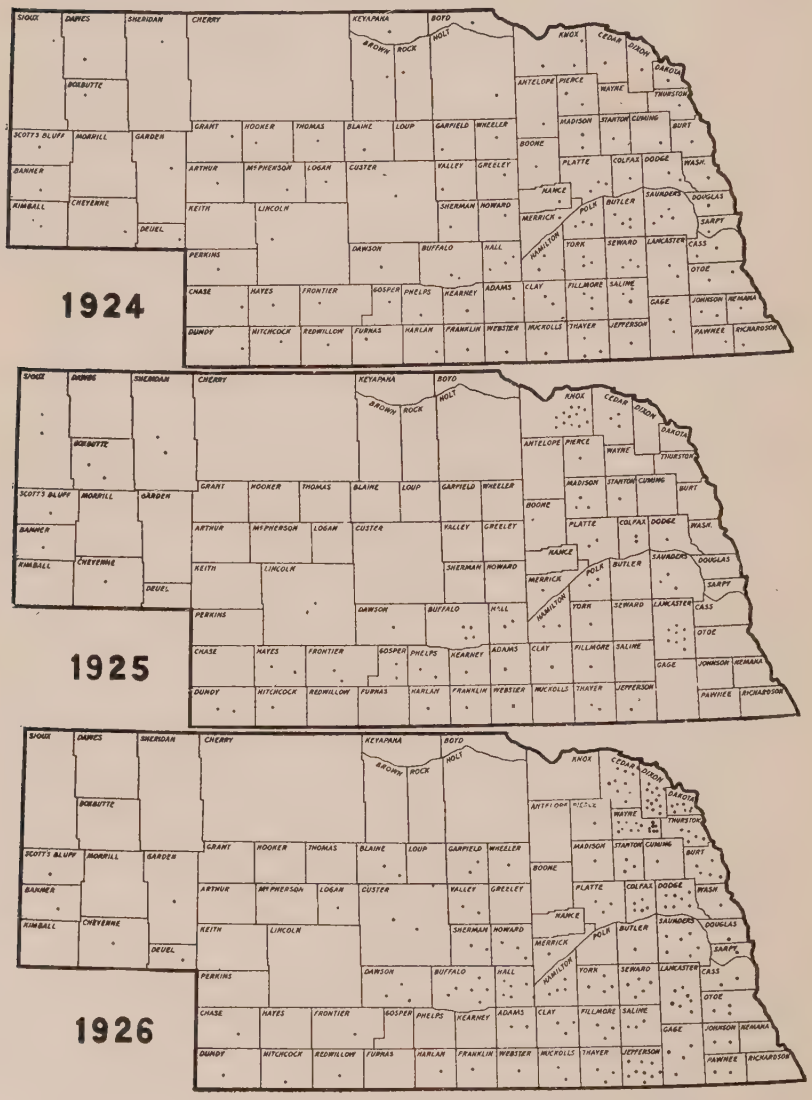

FIG. 9.— Distribution of the rust collections made in the state for the seasons 1924, 1925, and 1926.

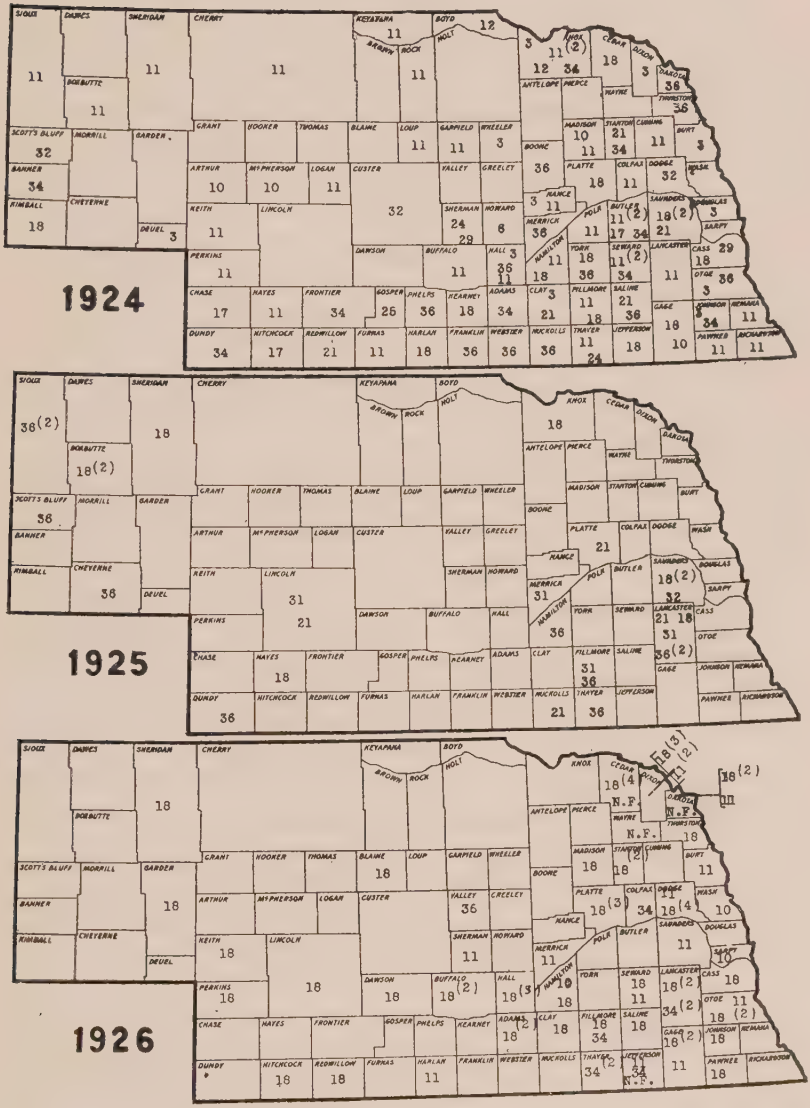

FIG. 10.— Distribution of the physiologic forms of *Puccinia graminis tritici* collected in the state during the seasons 1924, 1925, and 1926.

Form 31. Polk County.
Form 36. Cheyenne, Dundy, Hamilton, Scotts Bluff, and Sioux (2) Counties.

These 4 physiologic forms are also the ones which were identified from primary uredinia. Forms 36 and 18 had a more or less state-wide distribution and appear to be the dominant forms. The other physiologic forms were not collected in sufficient numbers to make any statement regarding their prevalence in the state. From a single collection from Manhattan, Kansas, Forms 21 and 36 were identified.

During October, 5 collections were made on volunteer and fall-sown wheat in eastern Nebraska and the following forms identified:

Form 18. Lancaster and Saunders (2) Counties.
Form 21. Platte County.
Form 31. Lancaster and Merrick Counties.
Form 32. Saunders County.

It will be noted that the first 3 physiologic forms listed above were collected as primary infection in early June and as secondary and succeeding generations of uredinia in July. Form 32 was picked up for the first time during the season. The prevailing form, namely 36, was not identified from any of the material gathered in October. Perhaps if more collections had been made it would have been found. Three collections were sent from Kansas, one on *Aegilops cylindrica* from Manhattan and two on volunteer wheat from Pawnee and Thomas Counties, during September and October. Forms 18, 21, and 36 were isolated from this material. These physiologic forms, as stated above, were collected earlier in the year in Kansas.

To summarize: During the season, 1925, 5 physiologic forms were found in Nebraska. Of these, 4 were collected in 1924, while Form 31 was new. Forms 18 and 36 were the dominant and widely distributed forms in 1925. The dominant Form 11, together with 9 other forms collected in 1924, was not found in Nebraska during 1925.

RESULTS OF IDENTIFICATION OF PHYSIOLOGIC FORMS IN 1926

During the season of 1926, 213 rust collections were obtained. Ten of these came from beyond Nebraska, while the rest were collected in 65 counties of the state and were found on the following hosts: Winter wheat (119), spring wheat (11), barley (18), *Hordeum jubatum* (39), *Agropyron smithii* (7), *Elymus* sp. (1), oats (5), and rye (1). Two collections of aecia on barberry were made but the spores were not viable after storage for about 4 months. The distribution of the collections made in 1926 is shown in Figure 9.

The *secalis* form of *Puccinia graminis* was collected 21 times in 9 counties of Nebraska and once near Belleville, Kansas (fig. 11). All but 4 of these collections were made near infected barbreries on *Hordeum jubatum* (9), *Agropyron smithii* (5), *Elymus* sp. (1), and barley (2). Most of these were found in Wayne County and represent several collections obtained on different hosts at different dates and distances up to a mile from the same barberry bush. In all, 11 collections were made in Wayne County near infected barberries and all were identified as the *secalis* form. The collections made in Cedar and Colfax Counties were each from near the same barberry. Very little wheat but some barley and rye are grown in the northeastern portion of the state. Therefore, most of the rust collections noted have been made on wild grasses. As in 1925, the *secalis* form was obtained from rusted grasses near infected barberries in the vicinity of Belleville, Kansas.

Unfortunately no rust transfers were successful in the greenhouse from aecia and rusted grasses found under barberries collected during May and early June. However, a number of collections on *Hordeum jubatum* (8) from under or near infected barberries made in late June and during July were successfully transferred to wheat and the physiologic forms determined in the greenhouse. These collections were all made in 4 northeastern counties; namely, Burt (1), Cedar (1), Dakota (2), and Dixon (4). Form 11 was obtained from the material in Burt, Dakota, and Dixon (2) Counties, while Form 18 was found in Cedar, Dakota, and Dixon (2) Counties. Thus while the majority of rust collections from near barberries in this section of the state were identified as the *secalis form*, a number of physiologic forms of *Puccinia graminis tritici* were found in 4 of these counties. It is interesting to note that while Form 11 was the dominant form in 1924, not a single collection of this form was made in 1925, altho it was found near rusted barberries in 1926, as well as in other localities not directly traceable to barberries.

Only 3 physiologic forms were identified from the primary uredinia not directly traceable to infected barberries, the dates of collection of which are shown in Figure 8. These forms, with their locations, are listed below:

Form 10. Hamilton, Sarpy, and Washington Counties.
Form 11. Jefferson and Otoe Counties.
Form 18. Buffalo (2), Cass, Gage (2), Garden, Hall, Keith, Lancaster (2), Lincoln, Otoe, Perkins, Platte (2), and Seward Counties.

As in previous years the first uredinia were found in some counties of the southeastern tier. Both Forms 11 and 18 were first found here and later in localities to the north. Form 18

was the dominant form found in the early collections, as will be noted. One collection was found at Yankton, South Dakota, June 9. Likewise, it was found on wild grasses near infected barberries in July in some of the northeastern counties.

Any collections made after June 17 were listed as secondary infections. Below are listed the forms found during the latter part of June and July:

Form 11. Harlan, Sherman, and Seward Counties.
Form 18. Adams, Blaine, Cedar (2), Dakota, Dawson, Dixon, Dodge, Hall, Hamilton, Hitchcock, Madison, Red Willow, Saline, Stanton (2), Sheridan, and Thurston Counties.
Form 34. Thayer County.
Form 36. Valley County.
New Form. Cedar, Dakota, Jefferson, and Wayne Counties.

Form 18 appears to have the widest distribution of any of the physiologic forms picked up during the summer. Form 11, while rather scattered, was picked up only 3 times. Both Forms 34 and 36 were found only once. The latter was collected 6 miles from an infected barberry. It seems strange that Form 36, which was prevalent during 1925, was not found more often in 1926.

The physiologic form collected 4 times in the eastern part of the state is designated as new because it does not conform to any of the 37 physiologic forms described by Stakman and Levine (13). Its reaction on the 12 differential hosts is as follows:

	Range	Mean		Range	Mean
Little Club	3–4	4	Arnautka (Speltz Marz)	0–0;	0;
Marquis	3–4	4	Kubanka	0–4;	X
Kanred	0–0;	0	Acme	3–4	4–
Kota	3–4	3+	Einkorn	0–0;	0;
Arnautka	0–0;	0;	Vernal (Emmer)	0–0;	0;
Mindum	0–0;	0;	Khapli	0–0;	0;

No suggestion as to the origin of this new form in Nebraska is offered.

Three physiologic forms were found in the 17 collections made in October on fall-sown or volunteer wheat. The forms and counties in which they were found are given below:

Form 11. Dodge, Gage, Merrick, and Saunders Counties.
Form 18. Adams, Clay, Dodge, Fillmore, Hall, Johnson, Otoe, Pawnee, and Platte Counties.
Form 34. Clay, Colfax, Jefferson, Lancaster (2), and Thayer Counties.

Again it is found that Form 18 is the dominant and widely distributed form, followed by Form 11. Form 34, while found only once during the summer, seems to be fairly well scattered over southeastern Nebraska.

Two collections on winter wheat and *Hordeum murinum* sent from Sacaton, Arizona, in May yielded Forms 11 and 10 respectively. Likewise, 2 collections from Texas made in early and late May on winter wheat were also found to be Forms 10 and 11. Thus, the same physiologic forms were found in 2 widely removed states to the south and southwest of Nebraska. One collection made in Kansas in June proved to be Form 34, and one on volunteer wheat, made in October, was identified as Form 18. One collection made in western Iowa in June on winter wheat also yielded Form 18.

To summarize: During the season of 1926, 6 physiologic forms of *Puccinia graminis tritici* were found in Nebraska, including *P. graminis secalis* collected a number of times in the northeastern part of the state on grasses near infected barberries. Forms 11 and 18 also were identified from rusted *Hordeum jubatum* found near infected barberries in the same section. Form 18 was the dominant and most widely distributed of the forms. Altho Form 11 was not found in 1925, it was identified from collections made in eastern Nebraska, including material from near infected barberries in 1926. The form designated as new made its appearance for the first time in 1926. Forms 10 and 34 were found in 1924 in more or less the same region where they were picked up in 1926. Form 36, one of the dominant and widespread forms in 1925, was found only once in central Nebraska. Forms 21 and 32 present in 1924 and 1925 in small numbers, and Form 31 found in 1925 only, were not recovered from any of the collections made in 1926.

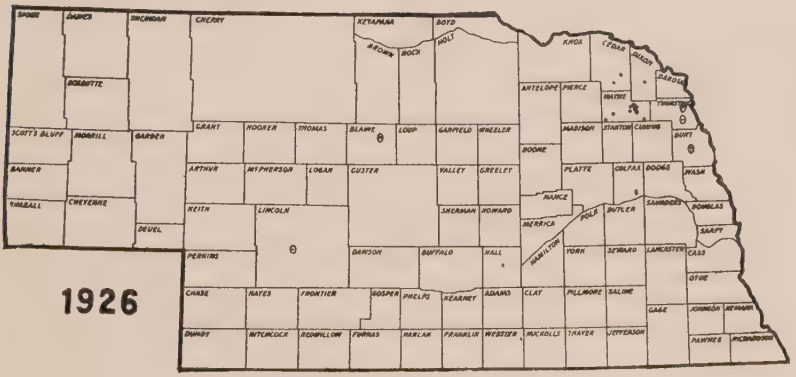

FIG. 11.— Distribution of *Puccinia graminis secalis* in Nebraska, 1926. The dot represents collections made near infected barberries, and the dot and circle, collections not traceable to barberries.

DISCUSSION

In Table 4, a summary is given of the annual occurrence of the physiologic forms of *Puccinia graminis tritici* found in Nebraska for 3 years. The outstanding feature is the prevalence of Form 18 during the 3 years. This form has been found as primary uredinia in the eastern part of the state in early June, as secondary and succeeding infections during the summer, and again in October on volunteer and fall-sown wheat. Its distribution has been more or less state-wide during all three years. Further, in July, 1926, it was recovered from wild grasses near barberries in the northeastern part of the state. Of the few collections made in other states, it has been found in Kansas in 1925, and in Kansas, Iowa, and South Dakota in 1926. Therefore, it may be assumed that Form 18 was a prevailing if not always the dominant form in this region. No definite statement as to how much of this form originates on the barberries and from sources outside Nebraska can be made. It never has been recovered from the few collections made in the South, while the data of Newton and Johnson (5) indicate that it is not common in Canada.

As has been pointed out previously, Form 11 was the dominant and prevailing form present in Nebraska in 1924, having been found as primary uredinia early in June in the eastern part of the state, thruout the state during the summer, and again in the fall. Altho this form was common and widespread in 1924, not a single collection was made in 1925, in spite of the fact that material was collected in the same localities in which it was prevalent the year before. On first thought one would be inclined to the explanation that Form 11 had its origin in the South and reached Nebraska as a northward spread, either directly or thru successive generations of urediniospores. But some of this rust must have been present in 1925 in northeastern Nebraska to produce telial material, as it was identified from wild grasses collected in July, 1926, near infected barberries. During 1926, it again was found as primary uredinia early in June in the southeastern section of the state, and while some of the rust originated from barberries, a certain amount may have entered the state from sources outside Nebraska. It was isolated from material sent from Texas, and also Arizona, indicating that it was present early in the South and Southwest.

Form 10 was identified from material sent from San Antonio, Texas, and Sacaton, Arizona, in 1926. The 3 collections made in Nebraska in 1926 were all primary uredinia not directly traceable to local barberries, and were found only along the Missouri River Valley. This form was not found

in 1925, while 4 collections were made in 1924 over the state. Newton and Johnson (5) never found this form in Canada in the 7 years that they have been identifying physiologic forms.

Form 21 appeared in rather small amounts in 1924 and 1925, while it was absent in 1926. It was identified from material collected in Arizona in 1924, and from 2 collections in Kansas in 1925. It was not identified from any collection made in Kansas in 1926. In 1925 it was one of the dominant forms found in Canada (5).

In 1925, Form 36 was found in Oklahoma; later on, 3 collections were identified from Kansas and in southeastern Nebraska as primary infections. It was also present in July and August and later in October in 1924, while only one collection was made in 1926. During 1925, it appears that it entered Nebraska from Oklahoma and Kansas. Likewise, it was by far the most prevalent form in Canada the same year (5), altho it had not been reported from this region during the 2 preceding years. It seems very likely then that there was a widespread distribution of this physiologic form in 1925.

It seems odd that, altho Form 3 was rather prevalent in eastern Nebraska in 1924, no further collections have been made. Newton and Johnson (5) found this form prevalent in Canada during 1924, and they likewise fail to identify it from collections made in 1925.

Physiologic forms, 6, 12, 17, 24, 25, and 29, which were found in 1924, have not been collected since. In all instances barberries were or have since been found and eradicated in the same general localities where the collections were made. It therefore seems possible that these physiologic forms were more or less localized around these bushes, and since the bushes have been eradicated, these forms have also disappeared. Judging from the limited data at hand, it is probable that the eradication of the barberry will reduce the number of physiologic forms occurring in the state. In other words, the uncommon forms may be present only in occasional years, while the common forms seem to appear regularly from year to year.

It is interesting in this connection to compare the behavior of the more common physiologic forms found in Nebraska with one another. The only difference between Forms 3, 18, and 36 is their reaction on Kubanka, one of the differential hosts. Kubanka is resistant to Form 3, susceptible to Form 18, while a heterogeneous infection is produced by Form 36. Unless the same strain of Kubanka were used, the readings would not necessarily be the same (6). Likewise, Forms 21 and 34 react similarly to the differential hosts, except with

TABLE 4.—*Annual occurrence of the physiologic forms of Puccinia graminis tritici in Nebraska. 1924-26.*

	Number of times collected												
	1924				1925					1926			
Form No.	Primary uredinia	Secondary and succeeding uredinia	Fall uredinia	Total	Primary uredinia	Secondary and succeeding uredinia	Fall uredinia	Total	Uredinia near barberry	Primary uredinia	Secondary and succeeding uredinia	Fall uredinia	Total
3		10	2	12									
6		1		1									
10		4		4						3			3
11	3	27	4	34					4	2	3	4	13
12	1	1		2									
17		2	1	3									
18	1	7	5	13	1	4	3	8	4	16	21	9	50
21		4	1	5	2	1	1	4					
24		2		2									
25		1		1									
29		2		2									
31					2	1	2	5					
32		3		3			1	1					
34		9		9							1	6	7
36		8	3	11	4	6	10				1		1
N.F.[1]											4		4
Total No. of forms				14				5					6
No. of collections				102				33					78

[1]N.F.—New physiologic form.

Kanred, which is resistant to the former and susceptible to the latter.

During the 6 years that we have had the physiologic forms of *Puccinia graminis tritici* under observation, no evidence has been obtained to show that they are either unstable or mutant. In other words, a physiologic form once isolated and pure will always react the same way on the differential host. Form 21, for example, has been carried thru many successive generations of urediniospores for 4 years in the greenhouse and maintained in the humidity chambers over a period of 6 months or more during the summer season, and still it reacts the same as it did when first obtained. However, there are differences in the expression of the reaction of the same type of infection on the differential hosts when two or more collections of Form 21 are compared under the same environmental conditions, altho Form 21 is very stable in this regard. Perhaps the greatest difference occurs in collections of Form 11. At times, a collection of this form will be very virulent on the differential hosts, while other collections will produce very weak infections. There is a very definite and tangible difference in the virulence of different collections of Form 11 on the differential hosts. In other instances, the difference in the reaction of various collections of one physiologic form is intensified on just one or more of the differential hosts. Thus, while one collection of a physiologic form will produce the same type of infection on the differential hosts over a period of years under greenhouse conditions, different collections of the same physiologic form may vary in the intensity with which they react toward the differential hosts.

SUMMARY

1. The urediniospores of stem rust do not overwinter in Nebraska.
2. Barberries have been found rusted at one time or another thruout the state. The degree of infection varies from year to year, from locality to locality, depending on weather conditions of the previous summer, fall, and spring influencing the viability of the teliospores and the maturation of the barberry leaves at the time sporidia are infectious.
3. During normal seasons, pycnia appear on the barberry between April 20 and April 26, aecia with mature spores between May 6 and May 10, and uredinia on grasses and grains near infected barberries about May 20 to May 25.
4. The *tritici* and *secalis* forms of *Puccinia graminis* have been the most common ones observed spreading from infected barberries. No clear, convincing case of the *avenae*

form has been observed spreading from barberries in this state.

5. The first uredinia not directly traceable to local barberries are normally found in southeastern Nebraska the first week in June. Within a week they appear in northern Nebraska, and in the western part of the state in about 2 weeks. This early infection of rust is found scattered in very small amounts over a wide territory as compared with the heavier local infection on grasses and grains near barberries.
6. The reduction of stem-rust losses during the past 6 years may be attributed in part to two factors; namely, a decrease in the number of remaining barberries, and, a lack of sufficient moisture for the development of the rust localized near infected barberries and from sources outside Nebraska.
7. A total of 16 different physiologic forms of *Puccinia graminis tritici* have been found in Nebraska, of which 14 were collected in 1924, 5 in 1925, and 6 in 1926. Eight of these physiologic forms can be classed as uncommon, as they appeared in very small numbers and were collected during only one season. The eradication of a large number of barberries may have eliminated some of these forms. The remaining physiologic forms have been collected one or more seasons in either small or fairly large numbers.
8. Six of the more common physiologic forms have been found in Kansas and in states south of Kansas, while two of them were collected near infected barberries in Nebraska. It can be assumed that some of these forms entered Nebraska as wind-blown urediniospores from these regions directly, or indirectly as progressive urediniospore generations.
9. The exact amount of stem rust present in Nebraska from year to year originating from either the barberry or from a source other than the barberry cannot be given from the data in hand. Not until the barberry is completely eradicated will the importance of the remaining source of stem rust be determined.

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